

ENSO impact on the Hydroclimate over the western United States in changing climate

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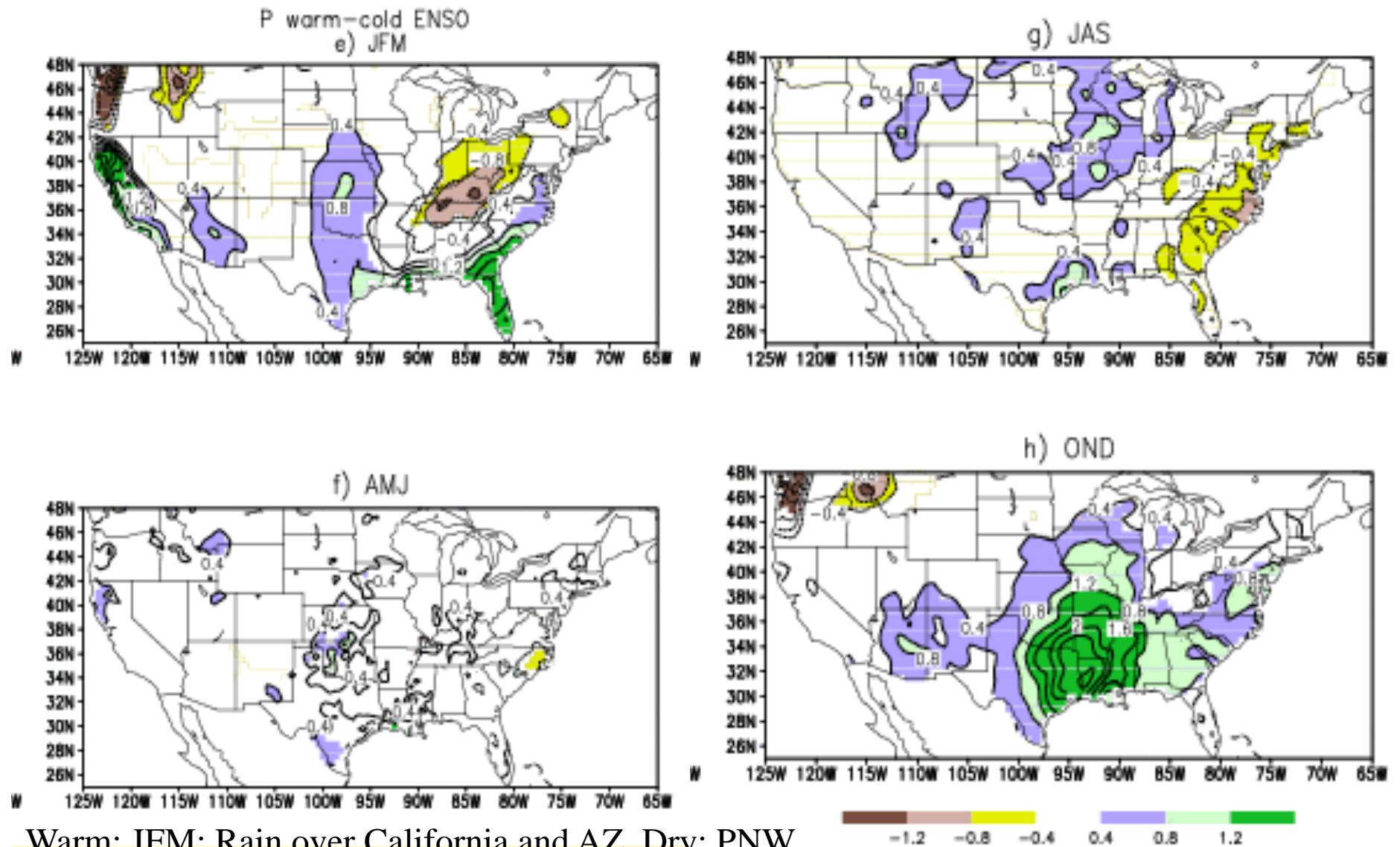
Climate is changing

Direct impact : trends

- e. g. Spring Tmin has been increasing over the Northwest and the West
- Early snowmelt over the western region (Stewart et al. 2005)
- Onset of spring comes earlier (Cayan et al. 2001)

Indirect impact– through ENSO or decadal modes

ENSO impact on P



Warm: JFM: Rain over California and AZ, Dry: PNW

OND : Dry :PNW, Wet: AZ

Questions

The impact of ENSO does not always obey the 'composites'. WHY?

- Each ENSO is different
- ENSO impact on regional climate is modulated by decadal modes

How?

- Climate warming has projection onto decadal or interannual modes. They modulate the regional climate

Decadal modes

- Trends
- Atlantic Multi decadal oscillation (AMO)
- Pacific Decadal Oscillation (PDO)
- PDO Barnett and Cayan (1998), Gershunov and Barnett (1998)

Observational Data

P and SM and runoff

- Monthly Precipitation (P) and surface temperature (T) over the United States from 1915-2006 (U. of Washington)
- Monthly mean Soil moisture and Runoff from ensemble NLDAS (VIC, CLM, Noah and Mosaic) (1915-2006)

SST and SLP

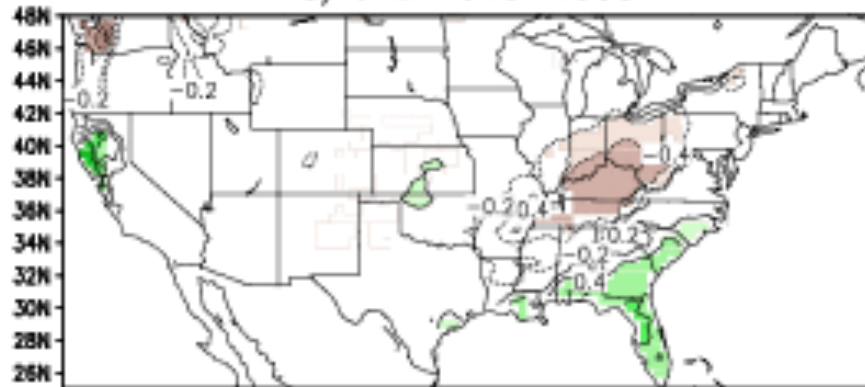
- SST- Smith reconstructed SSTs 1915-2006
- SLP – Trenberth and Paolino (1987)
- Anomaly- departure from monthly mean Climatology from 1915-2006

Procedures

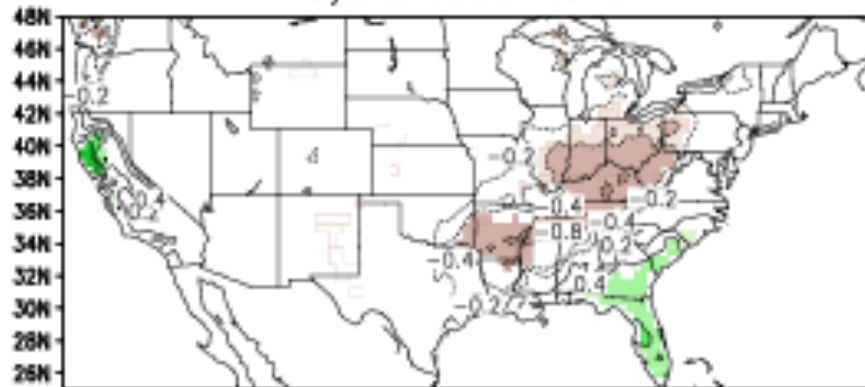
- Composites were formed for each season for (a) 1915-1955, (b) 1930-1970, (c) 1945-1985, (d) 1960-2000, (e) 1975-2006
- ENSO – Nino 3.4 index over 0.8 std (less -0.8 std)
- Results are given as composite: warm –cold weighted by the number of events
- Statistical significance is determined by the Monte Carlo method

Compo P diff warm-cold

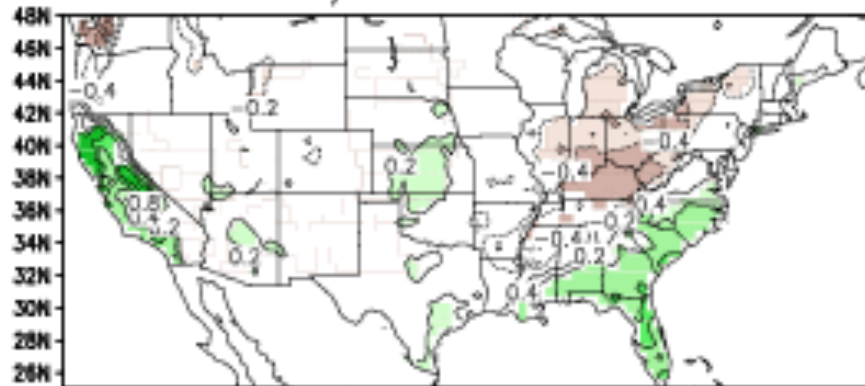
a) JFM 1915–1955



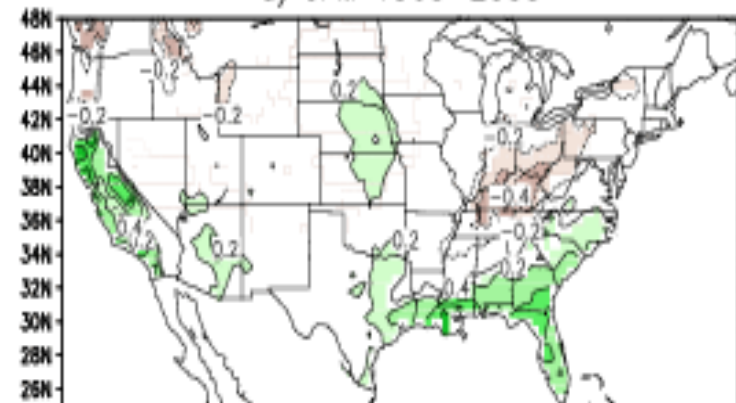
b) JFM 1930–1970



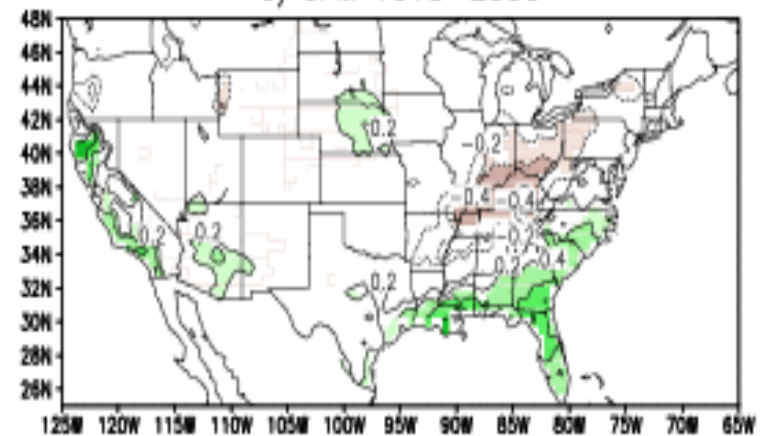
c) JFM 1945–1985



d) JFM 1960–2000

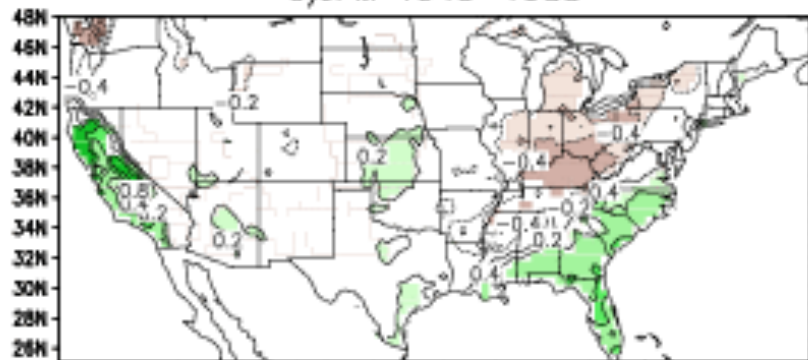


e) JFM 1975–2006

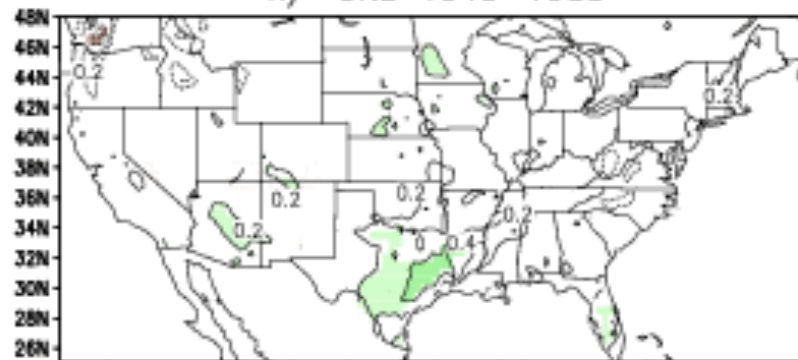


Seasonal shift

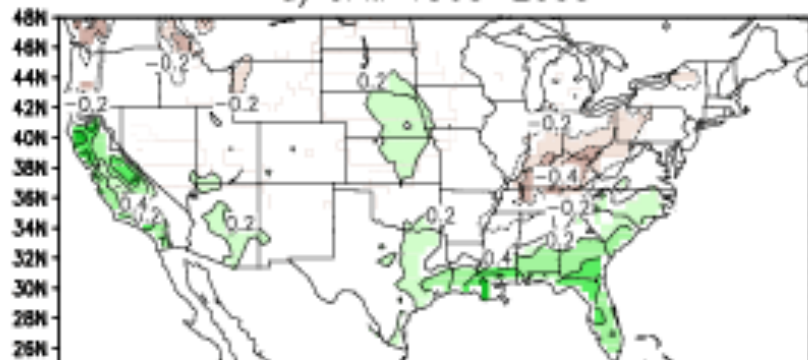
c) JFM 1945–1985



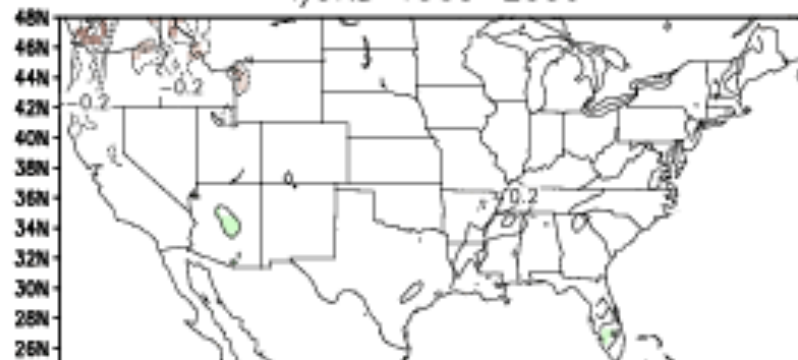
h) OND 1945–1985



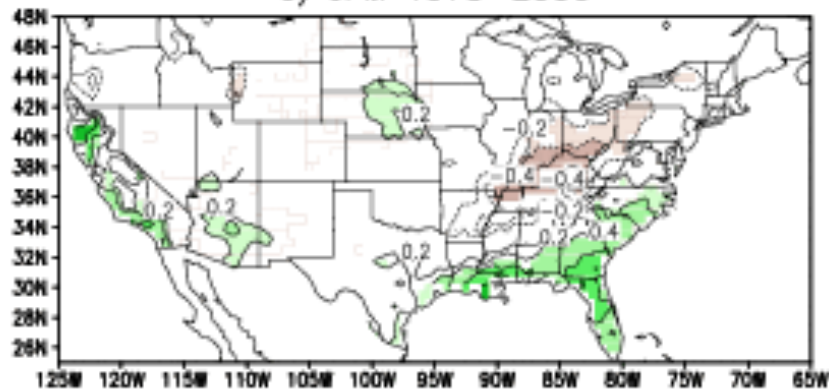
d) JFM 1960–2000



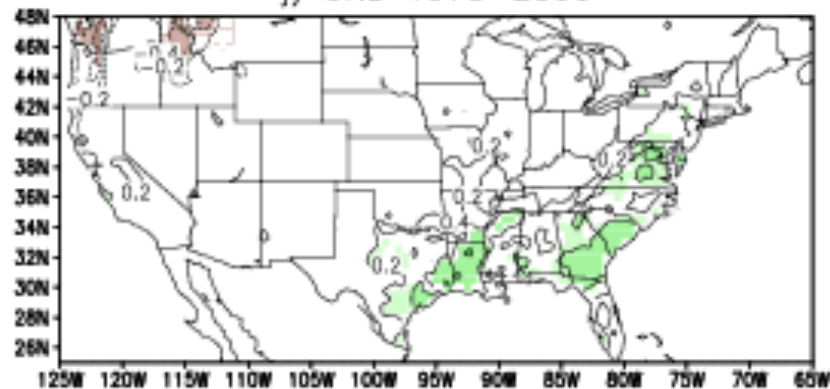
i) OND 1960–2000



e) JFM 1975–2006



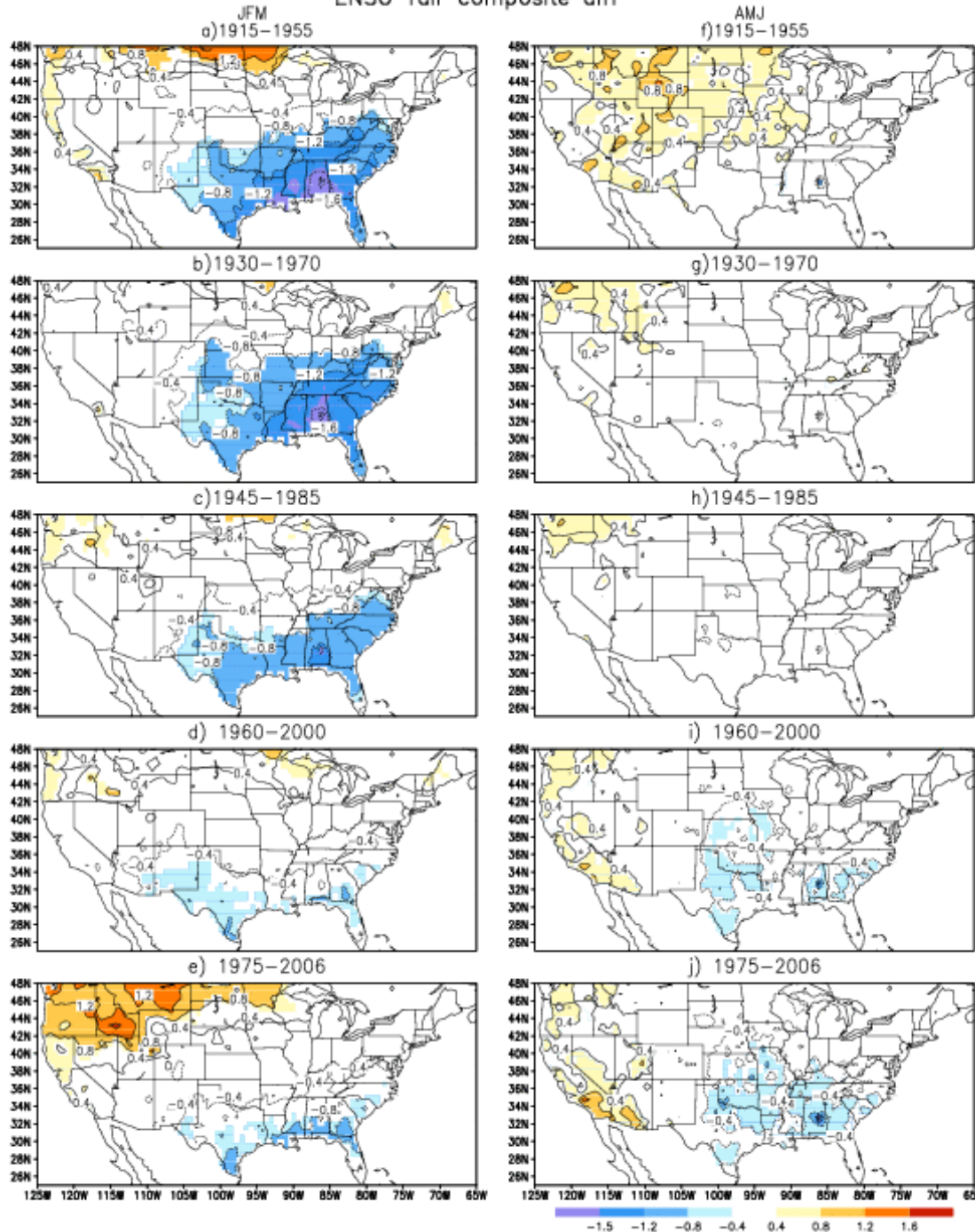
j) OND 1975–2006



ENSO-P teleconnections

- The impact of ENSO on P over the United States is not stationary.
- More warm ENSO events in the recent decades
- Impact over the southern Plains, the Southwest and California intensified over the recent decades (Warm=> wet, Cold=> drought)
- Impact over the Pacific Northwest comes early in Fall. (Warm= > drought, cold=> wet)

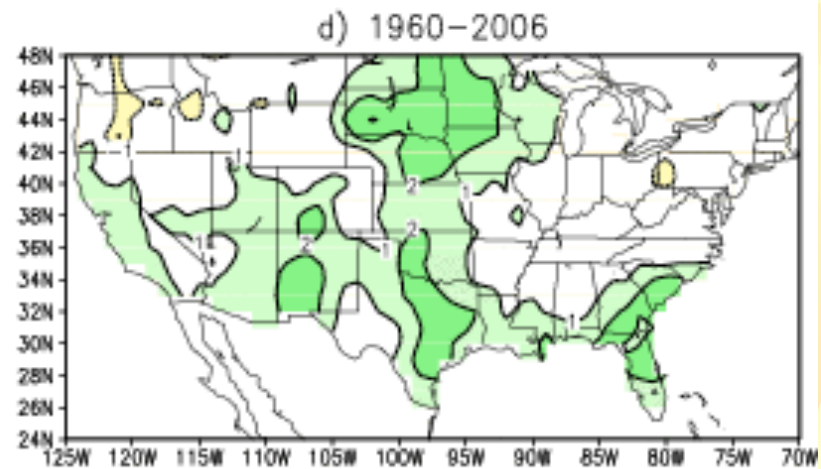
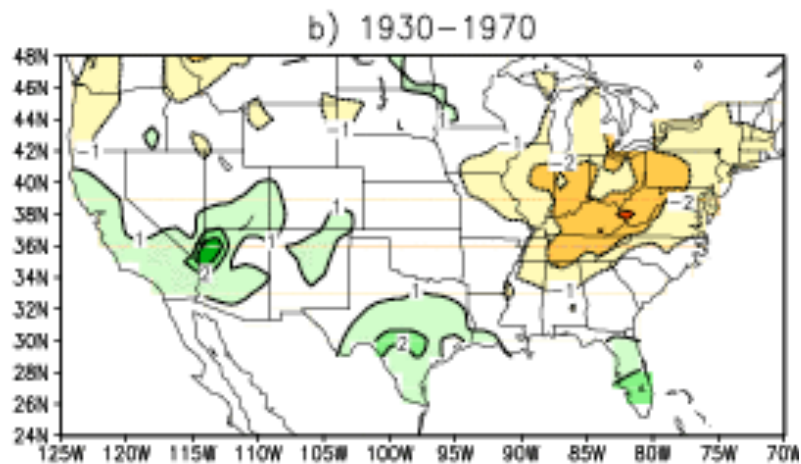
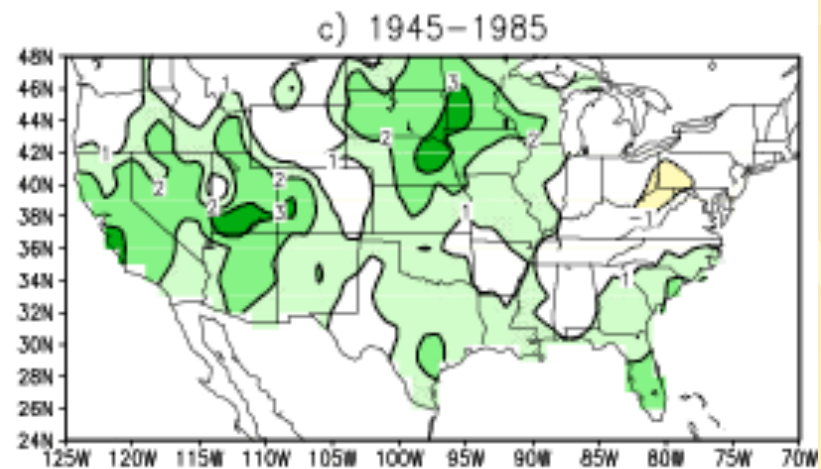
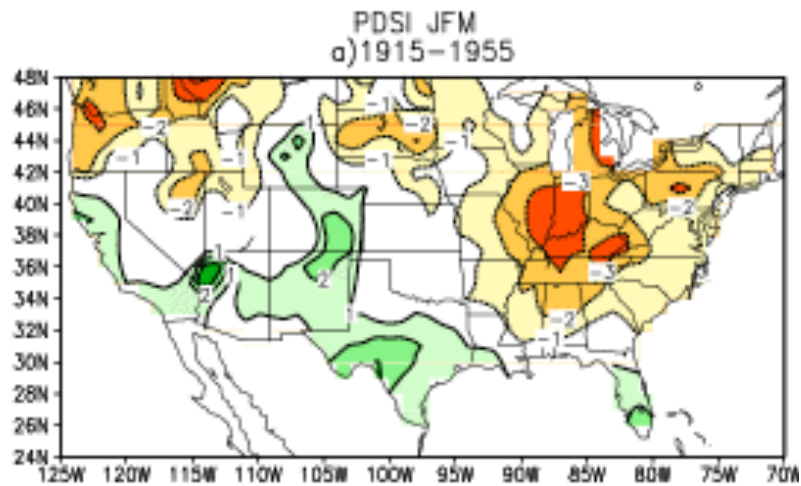
ENSO Tair composite diff



ENSO-T

1. Warm ENSO → cold over the South and warming over the North.
2. Changing
 - Cooling over the South has been weakening in winter.
 - Warming over the Pacific Northwest intensified after 1976
 - For California and the Southwest, spring is warmer in the recent decades.
 - The great Plains is cooler in spring

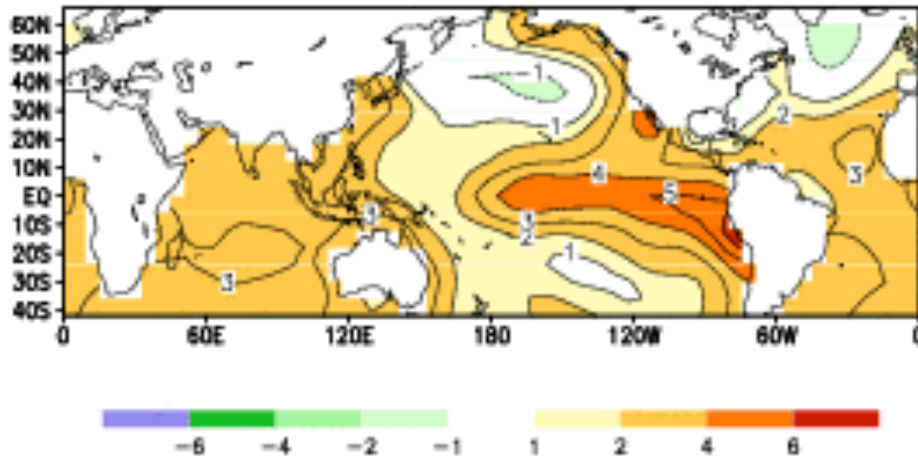
Composite PDSI



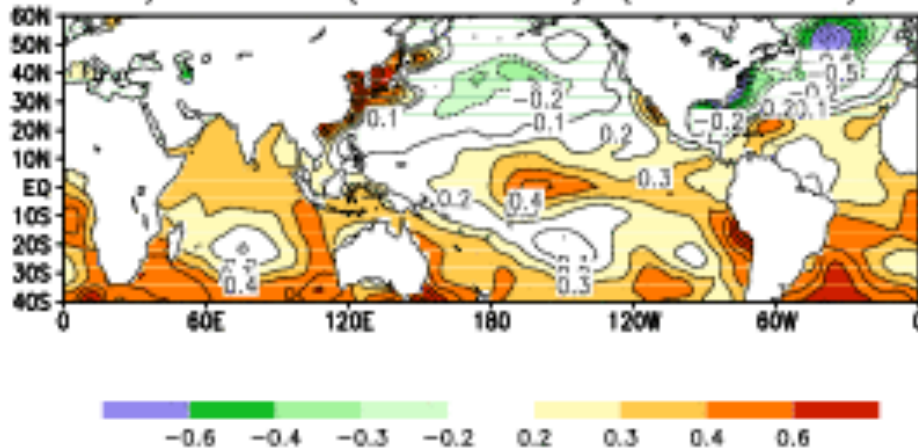
Climatology is changing

Annual mean EOF

a) EOF 1

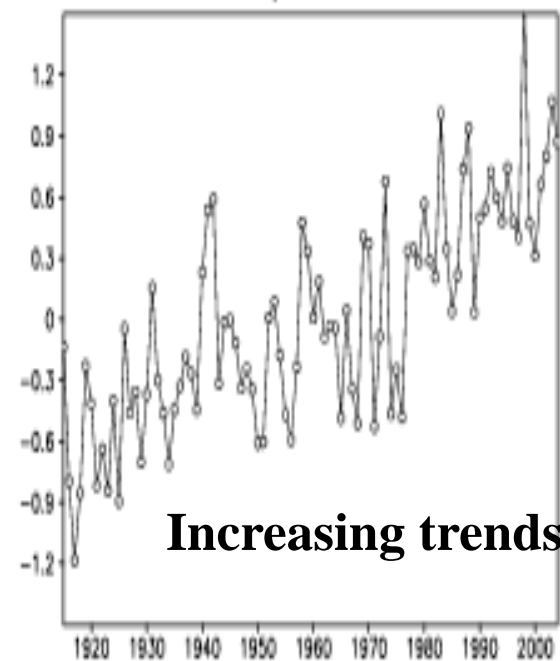


b) SST diff (1960–2006)–(1915–1955)



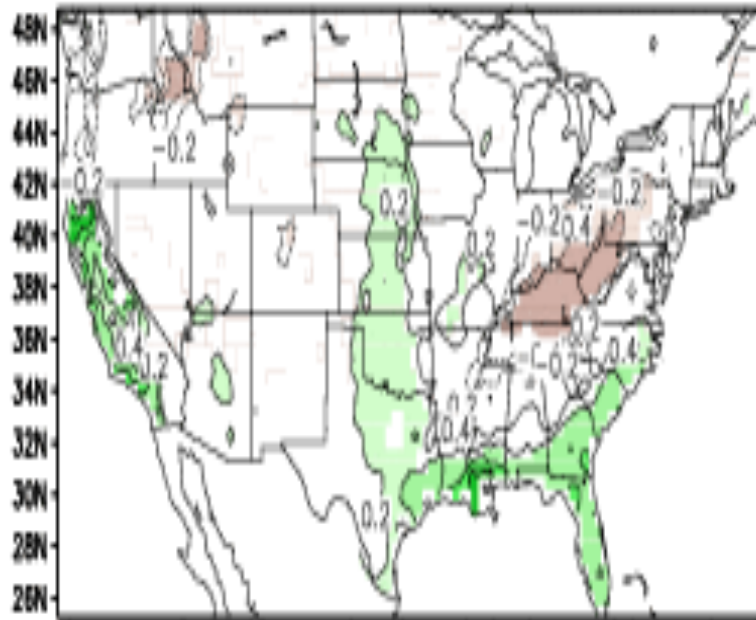
**More warm
ENSO events in
the recent
decades**

e) PC 1

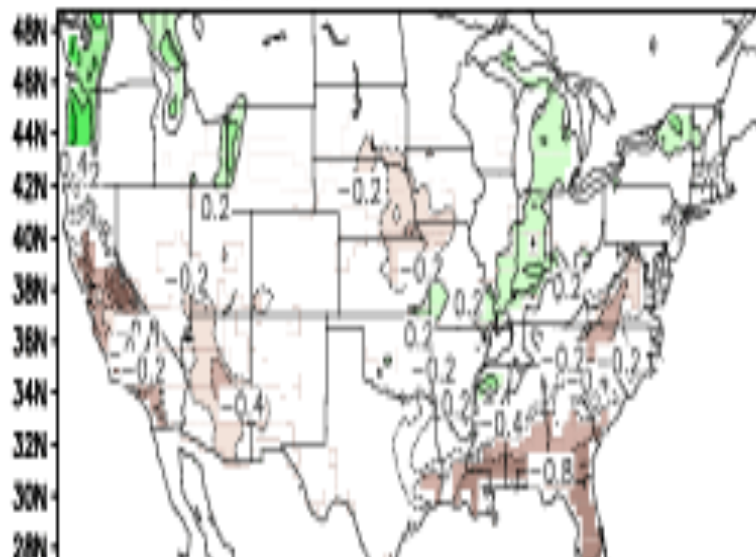


Increasing trends

f) pos JFM 1960–2000

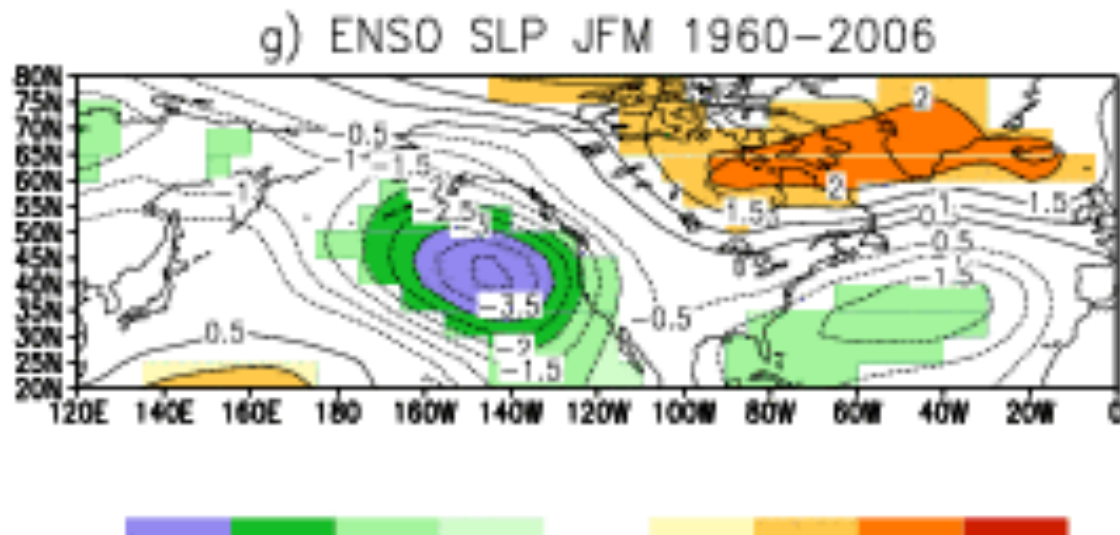
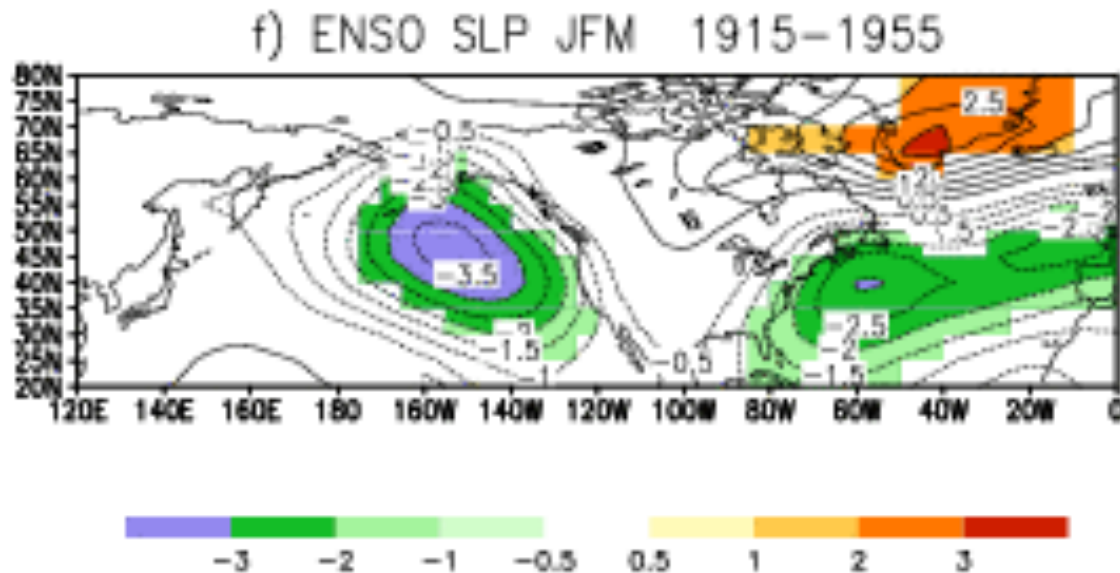


g) neg JFM 1960–2000



Composites for warm and cold ENSO events are similar with a sign reversal. They are equally strong.

Trend pattern alone does not explain the change of teleconnections.



SSTA pattern
change=>

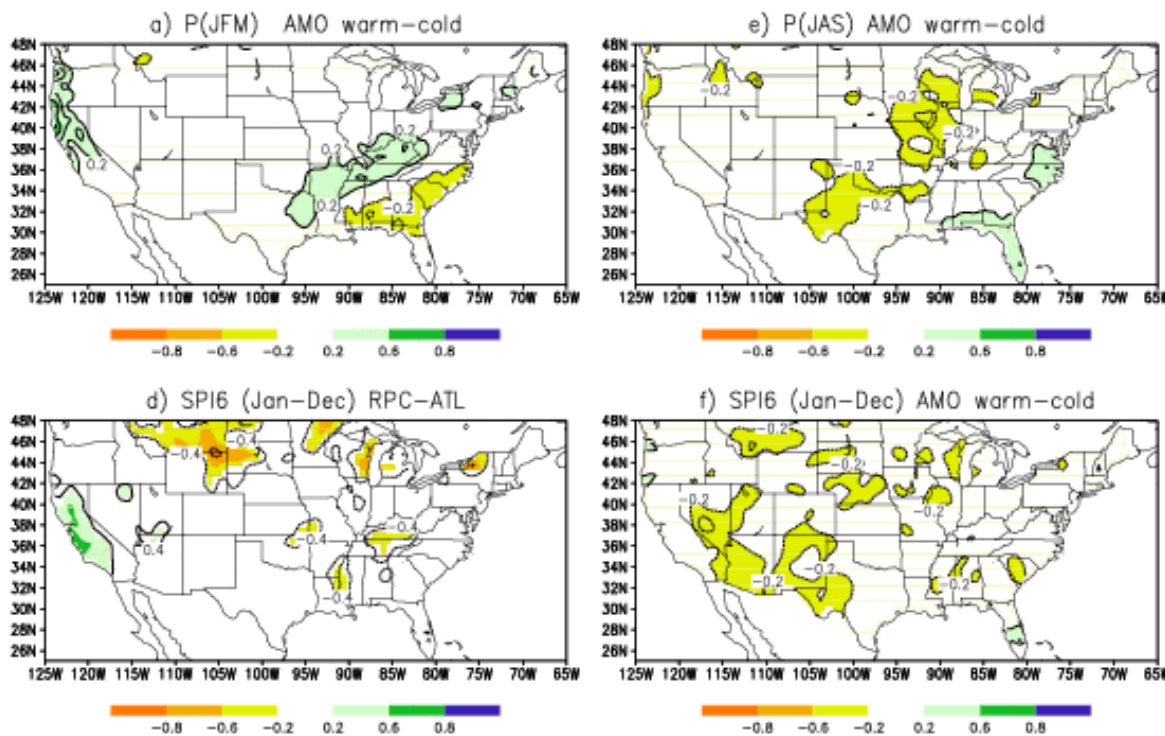
Responses to
ENSO are
changing

Decadal changes of ENSO impact

1. During warm ENSO , SSTAs increase over the central United States in the recent decades.
2. Circulation anomaly response depends on the strength and pattern of SSTAs.
3. Composites of SLP anomalies indicate that the Aleutian Low moved southeastward. The negative anomalies shift more inland over the West. Negative anomalies over the Atlantic shift eastward.
4. More rainfall over California, less cooling over the Gulf States.

Atlantic Multi decadal Oscillation

AMO composite warm-cold phase



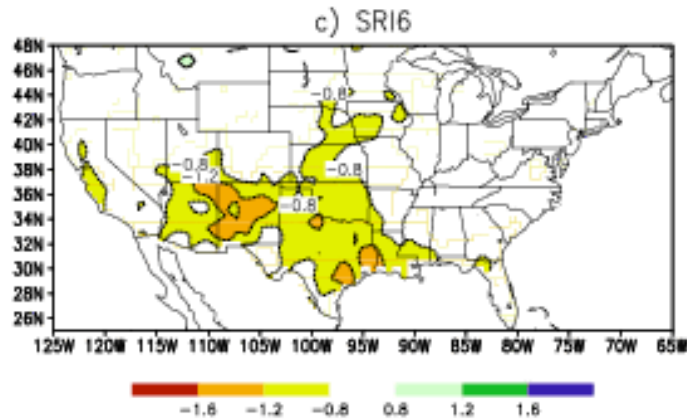
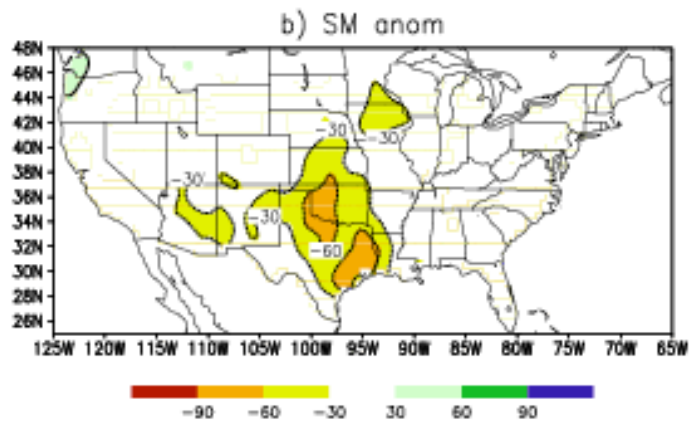
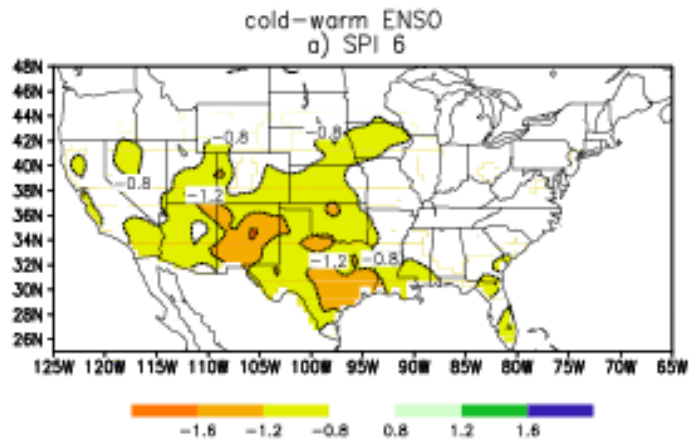
Decadal influence is small.

You can filter to get clearer signal, but the percentage of variance is small, so the net influence is small.

AMO warm 1930-1959, 1992-2006

AMO cold 1915-1925, 1965-1990

obs



Both
observations and

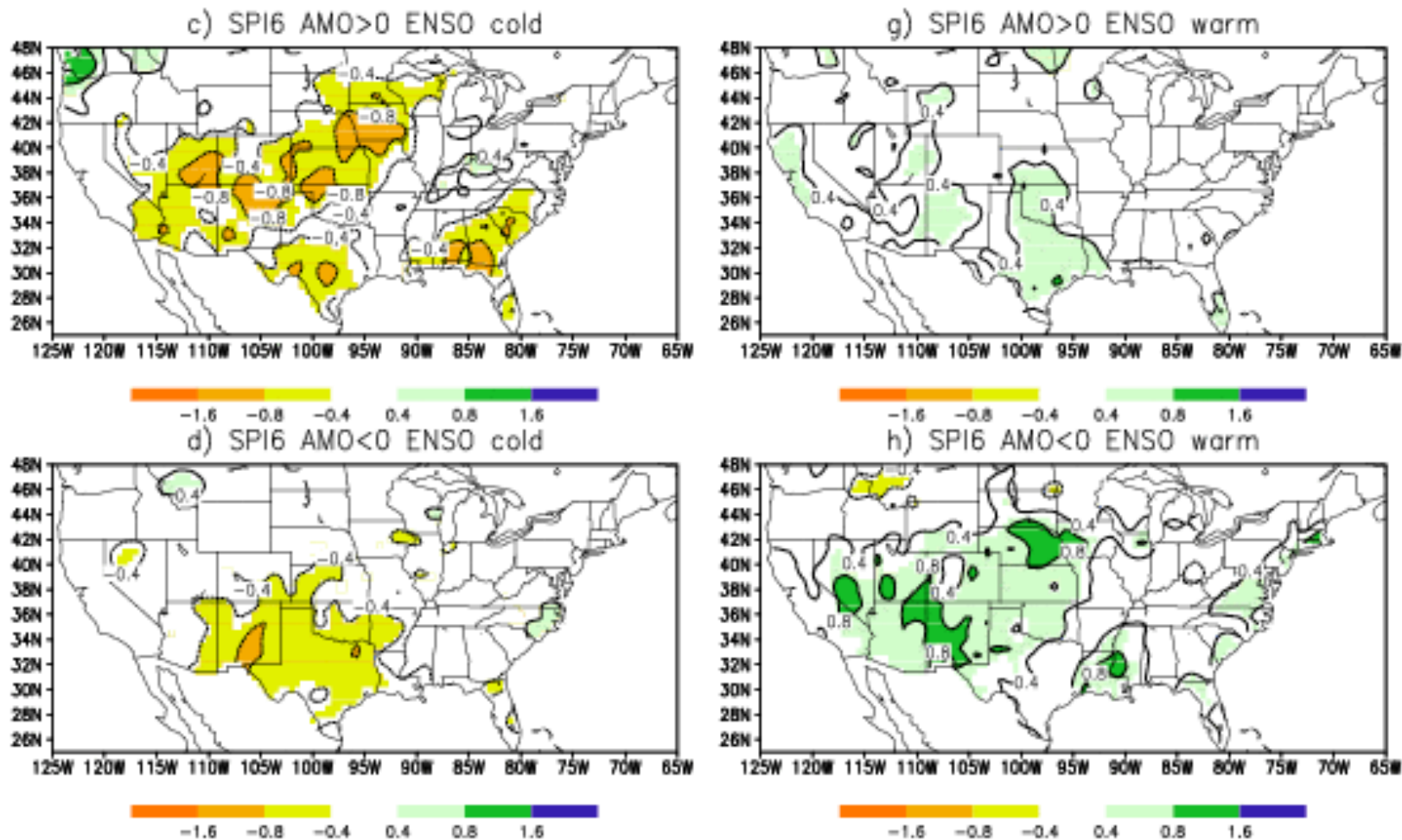
**Cold ENSO=>
drought over**

Great Plains

Southwest

AMO influence through ENSO

Composite of SPI6 with all seasons together for different phase of the AMO



Conclusions

- The impact of ENSO on regional climate over the United States is not stationary.
- Decadal modes and trends change the SSTA pattern or modulate the circulation pattern associated with ENSO.
- Seasonal forecasts: If you do statistically, you should use the most recent period. Because the impact of ENSO is indirect and non linear, to adjust trends may not be enough